NASA In-Space Inspection and Fabrication Workshop,
July 11th, 2003

Dry Adhesives for In-Space Repair

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e=m6

Gecko Setal Structure:

Macro/Micro/Nano Structure and Elasticity

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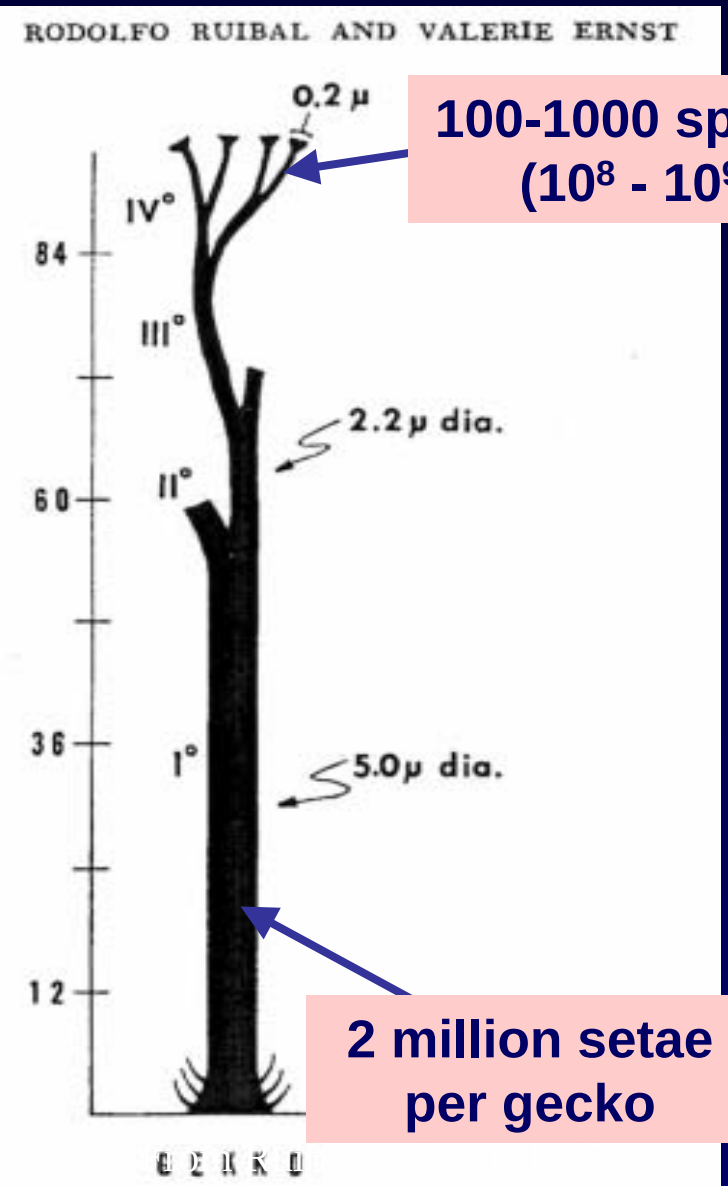
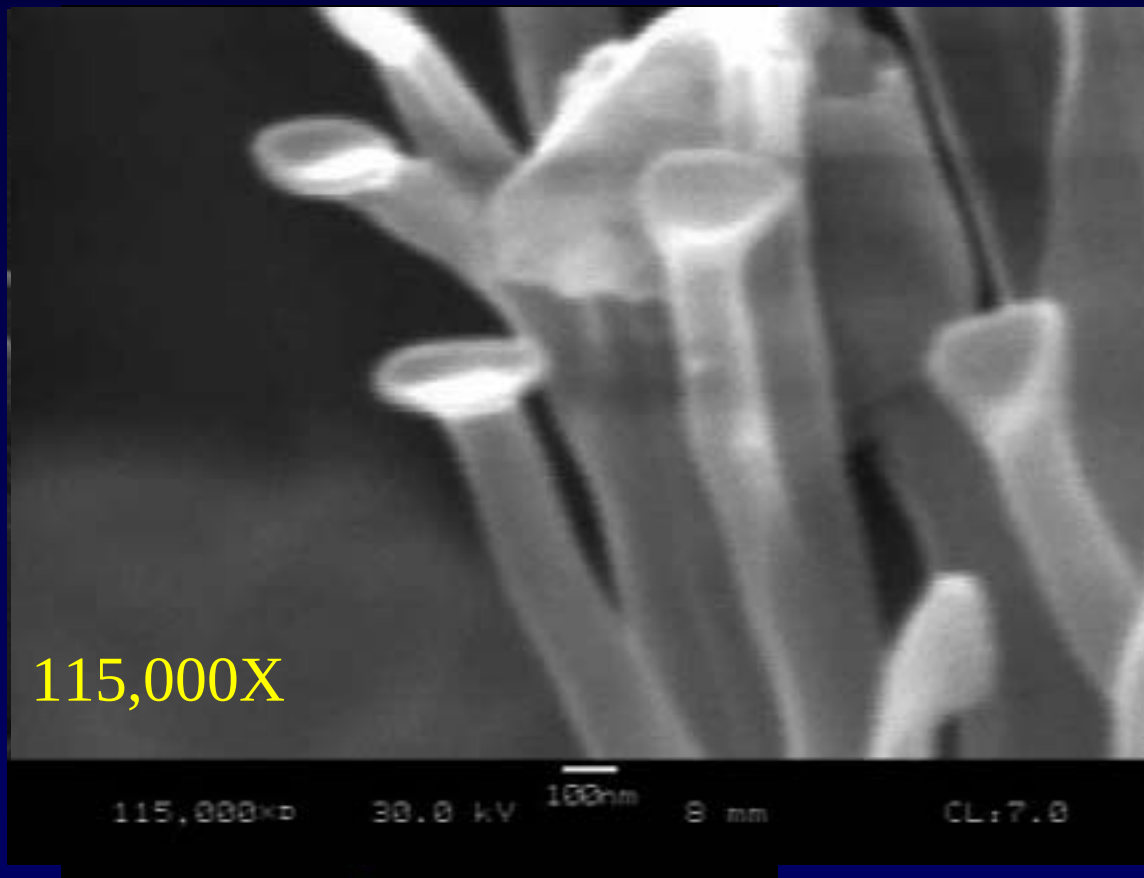


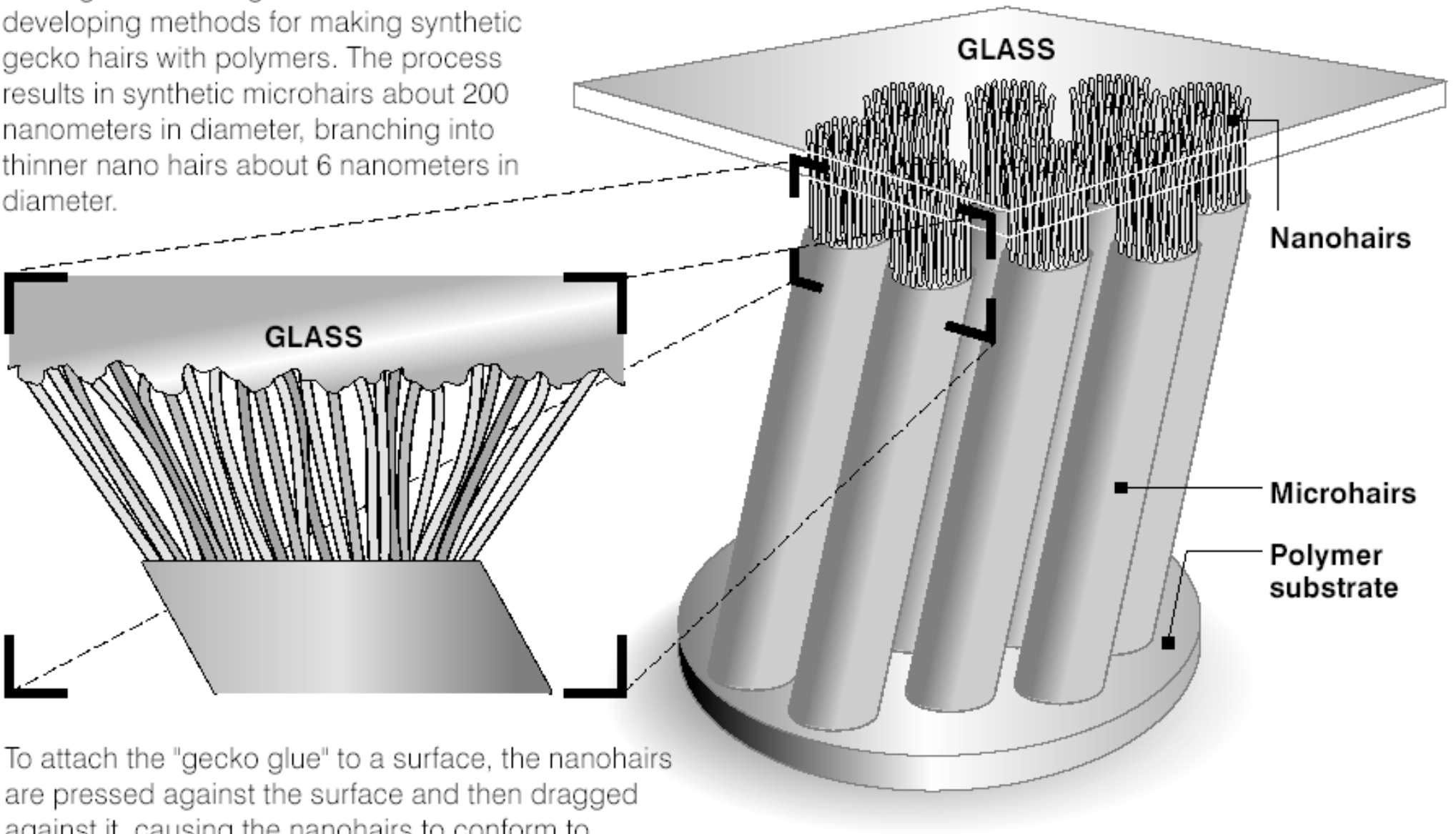
100-1000 spatulae per seta (10^8 - 10^9 per gecko)

2 million setae per gecko



Courtesy of Kellar Autumn, Lewis & Clark Univ.

Carnegie Mellon engineer Metin Sitti is developing methods for making synthetic gecko hairs with polymers. The process results in synthetic microhairs about 200 nanometers in diameter, branching into thinner nano hairs about 6 nanometers in diameter.

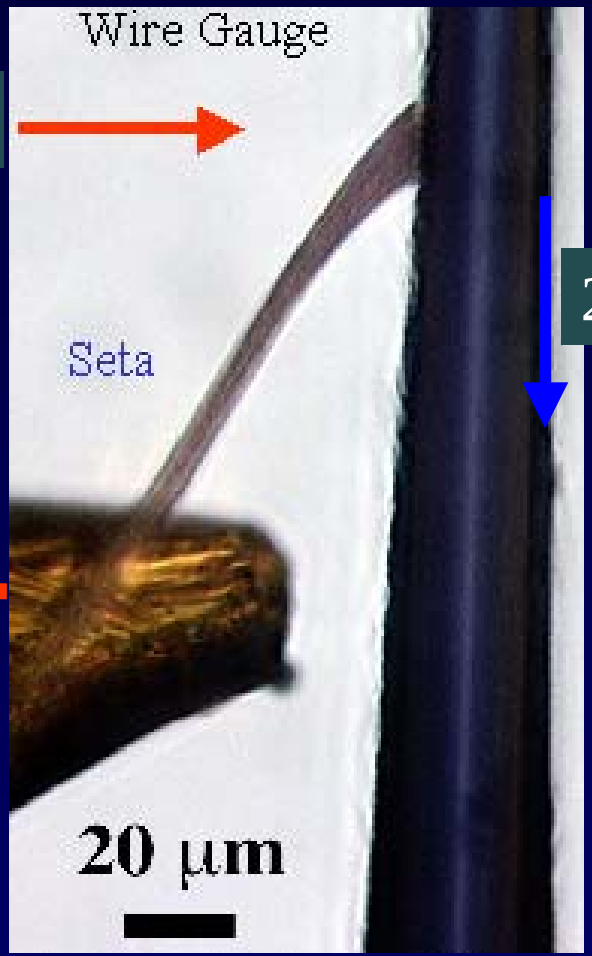


To attach the "gecko glue" to a surface, the nanohairs are pressed against the surface and then dragged against it, causing the nanohairs to conform to

Pressure Controlled Adhesion: Sticking and Releasing Mechanism

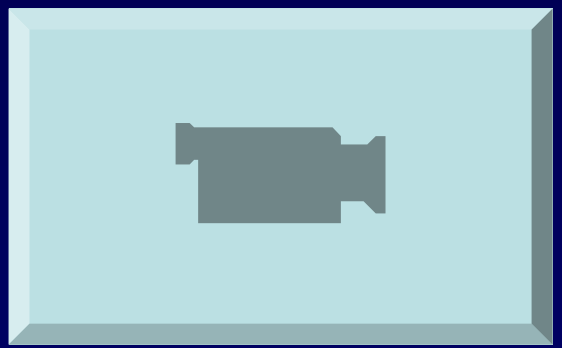
K. Autumn et al., ***Nature***, vol. 405, June 8, 2000.

1. Preload



2. Drag

3. Perpendicular Pull (Peeling by Rotation)



Gecko Foot-Hair Properties

- **Compliant micro/nano-hairs for adapting to smooth and rough surfaces: attachment forces about 10 N/cm^2**
- **Dry adhesion using molecular (Van der Waals) forces**
- **Works in atmosphere, vacuum, and in dusty environments**
- **Conducive to low temperature and low humidity**
- **Self-cleaning hairs – dirt sticks to surface more easily than to hairs**
- **Low power attachment and detachment: attach by normal loading and detach by torsional peeling of the hairs**

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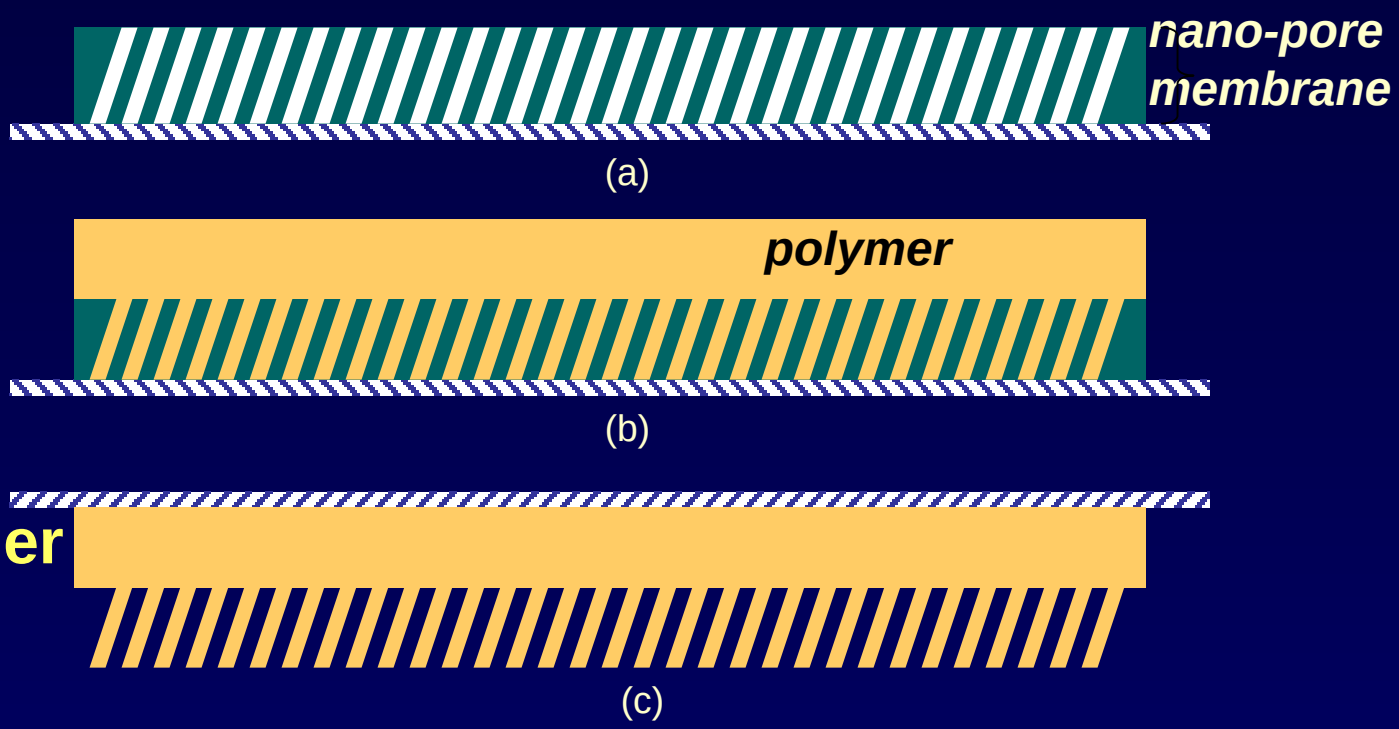
Polymer Hair Nano-Manufacturing by Molding Nano-Pore Membranes

Fix membrane

Mold polymer through the pores

Peel off the polymer or etch away the membrane



Integration of Micro- and Nano-Hairs

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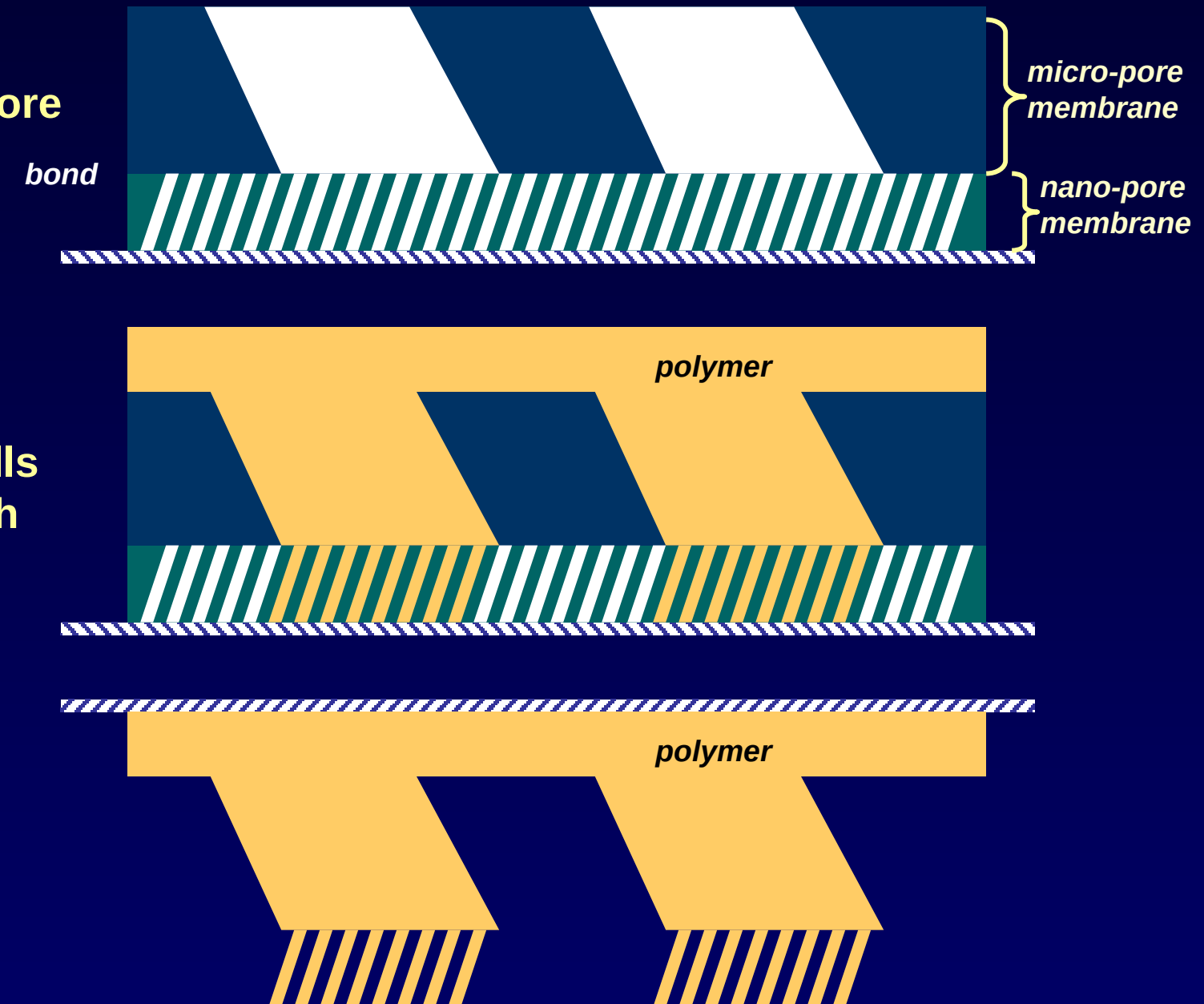
(a) Micro- and nanopore membranes are bonded to each other.

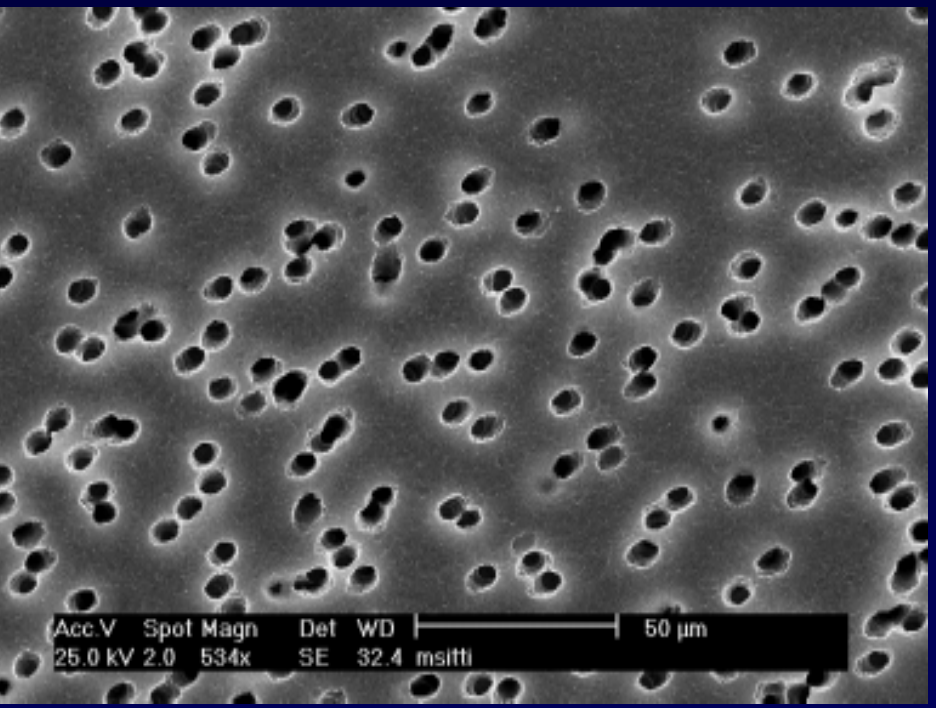
(b) Liquid polymer fills the pores in a high vacuum chamber.

(c) Membranes are etched away.

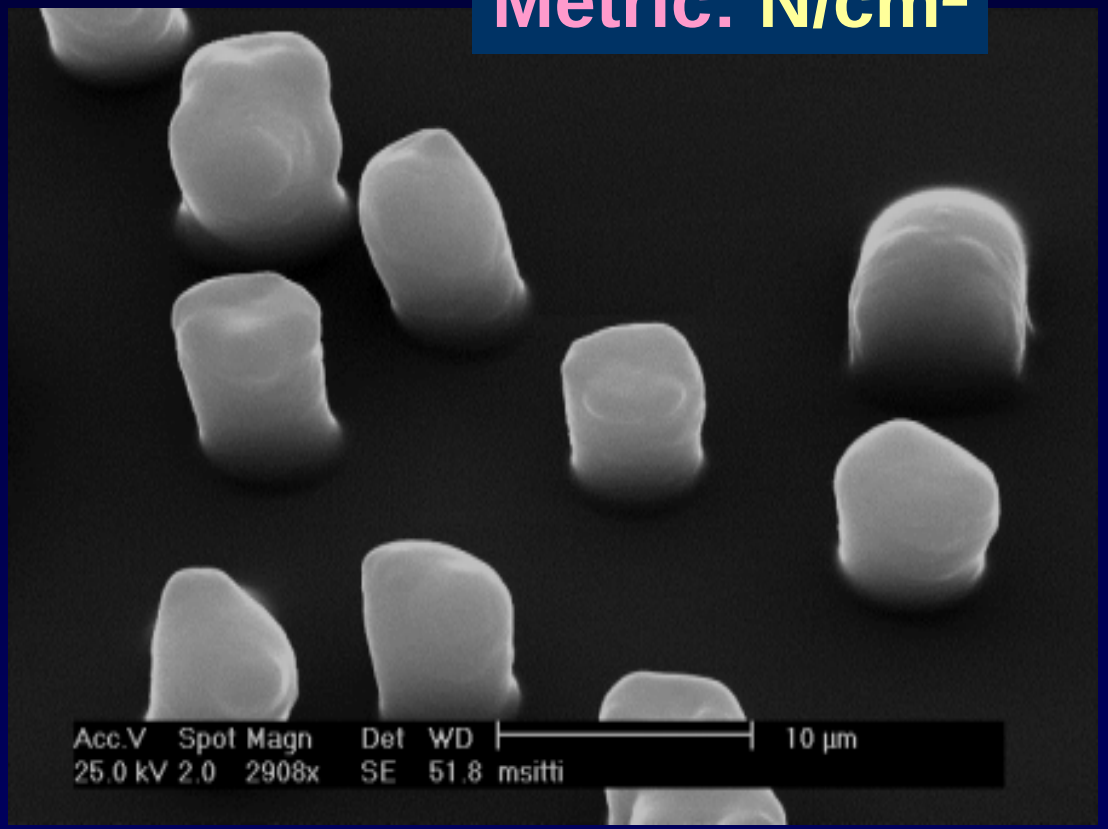


Silicone Rubber (PDMS) Micro-Hairs

Metric: N/cm^2



Polycarbonate membrane as the template



PDMS 5 µm (1:2) structures with around 0.1 N/cm^2 and 10^6 hairs/cm^2

M. Sitti & R. Fearing, *J. Adhesion Sci. & Tech*, July 2003.

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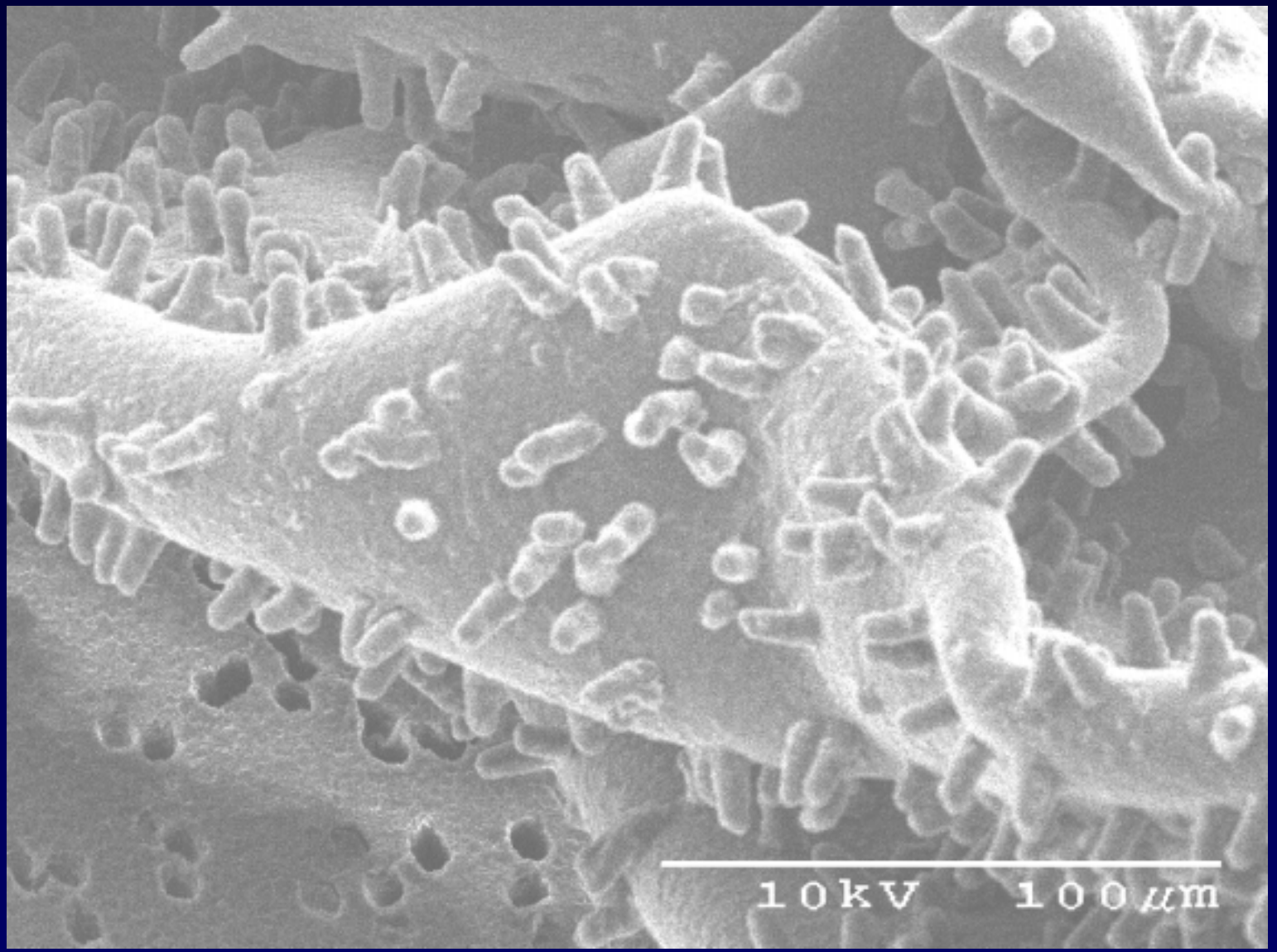
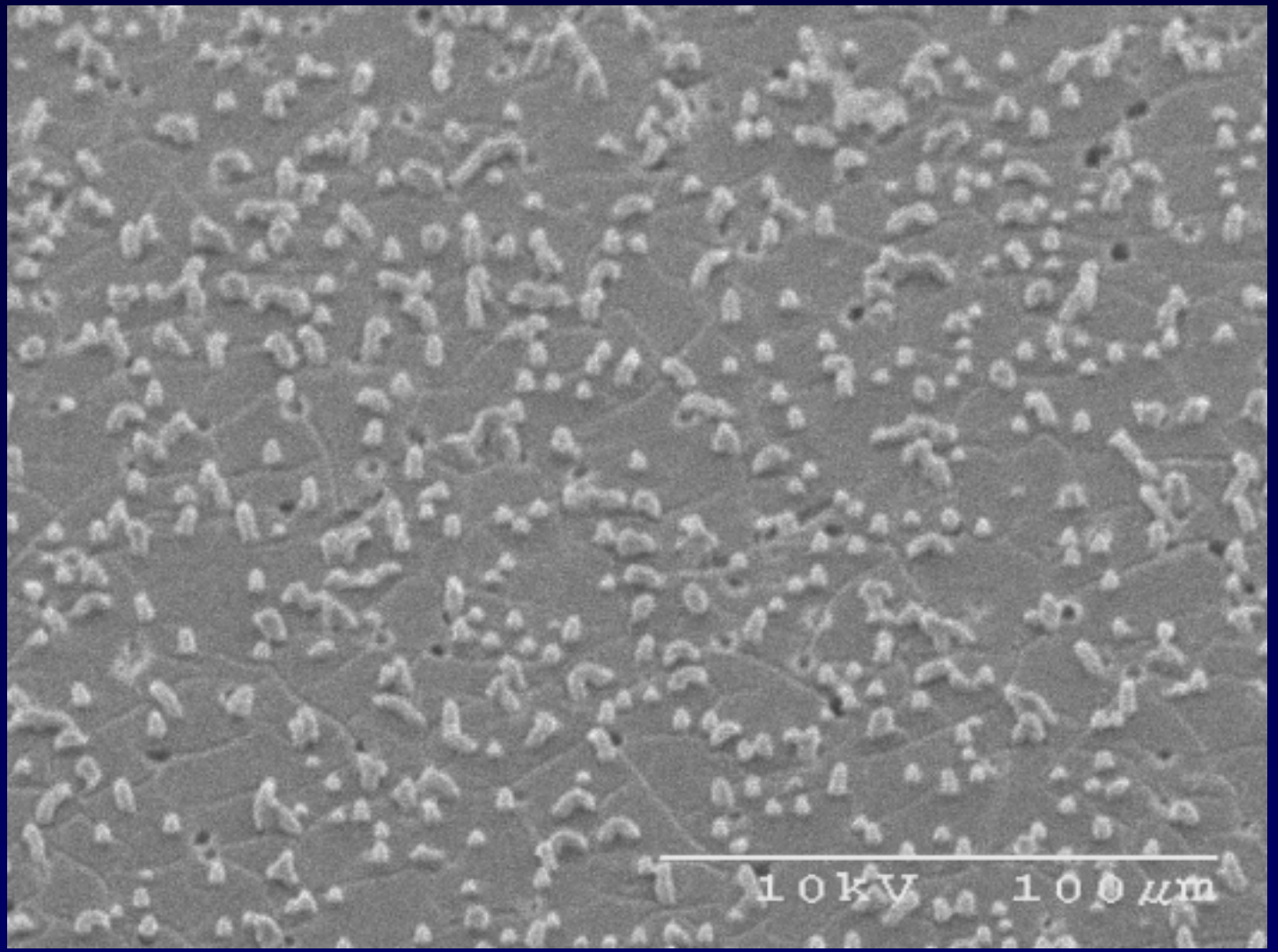
Polyurethane Micro-Hairs



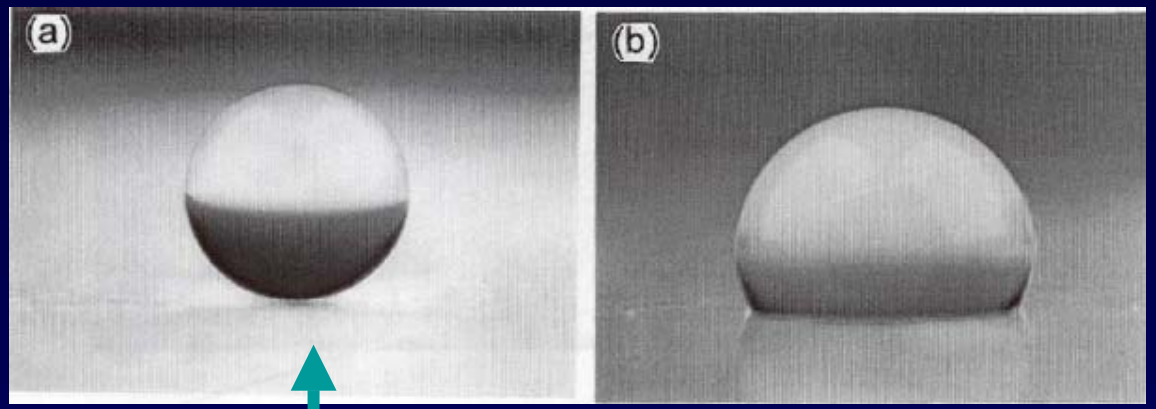
PDMS 2 μm Hairs

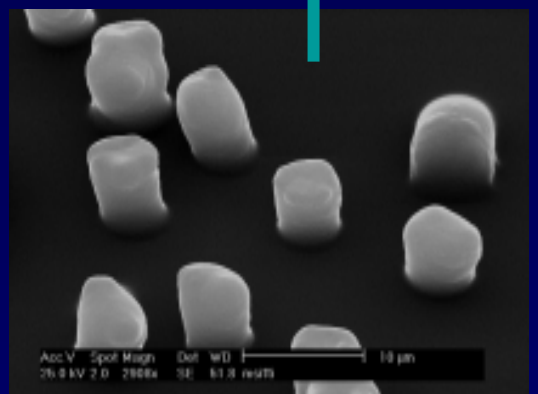


Self-Cleaning Materials: Roughness Effect; Lotus Effect

For a rough surface:

- **Hydrophobic surfaces are more hydrophobic**
- **Hydrophilic surfaces are more hydrophilic**





Dry Adhesives for In-Space Repair

- **Dry adhesive tape, ad-hoc Velcro, works on any surface (EVA or IVA) in vacuum and air**
  - **Adheres to any surface with rapid attachment and detachment**
  - **Eliminates need for mating surfaces and pre-scarring of surfaces**
- **Astronaut gloves, boots, and suits for stabilization and locomotion**
  - **Locomotion would eliminate need for personal propulsion system and fuel (reduced cost)**
  - **Stabilization mechanism with minimal energy required**
- **Temporary attachment for in-space construction/assembly**
  - **Temporary attachment using adhesive patches, permanent connection then made without need for additional equipment or procedures (i.e. truss assembly)**

Future Issues

- TR 1 -> TR-2,3
- Integrating micro (5 μm) and nano (0.2 μm) hairs in the same fabrication process
  - Synthetic hairs attachment strength expected to approach that of geckos
- Micro-gravity effects
- Synthetic adhesive characterization and optimization
- Alternative high volume manufacturing techniques
- Space related material and extreme temperature conditions
- Life-time (repeatability)

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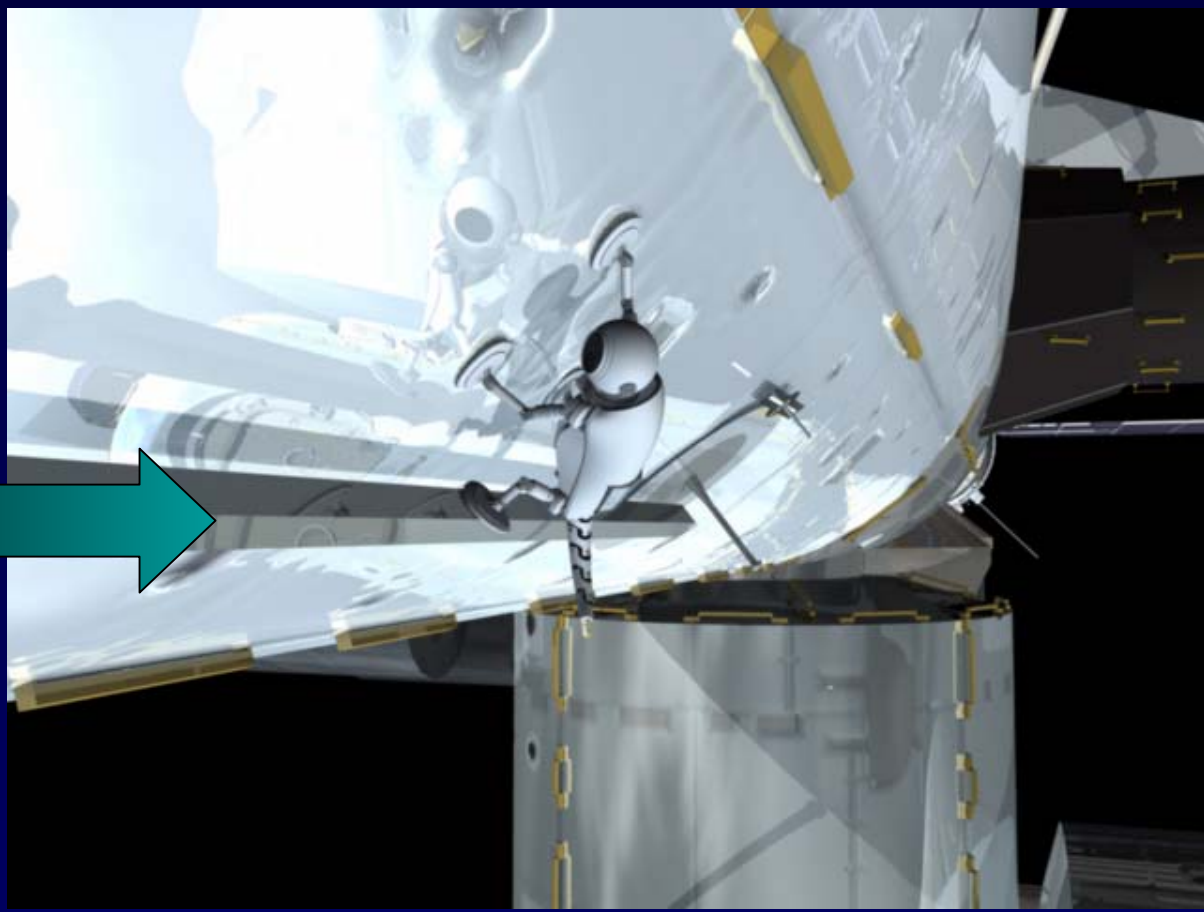
WallBots for EVA and IVA Inspection and Repair



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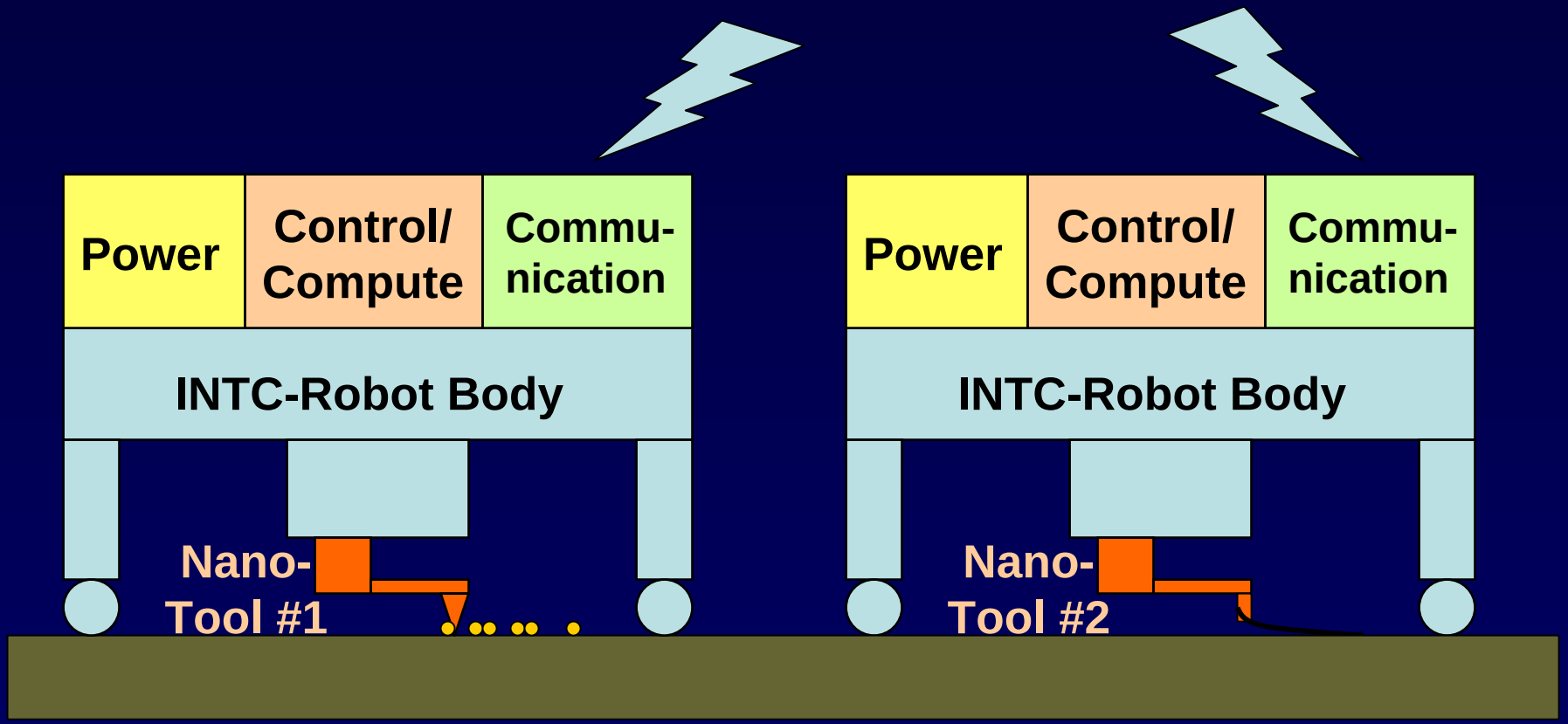
Micro-Capsules for Astronaut Health Monitoring and Repair (IVA)?

Integrated Nano-Tool Carrier (INTC) Robots for Miniature Micro/Nano-Manufacturing for Repair?



Acknowledgements

- **William ‘Red’ Whittaker & NASA RASC study sponsored by William Cerillo, JSC**

- **Neville Marzwell, JPL**

- **NanoRobotics Lab Members:**
  - **Grads:**
    - Burak Aksak, Bahareh Behkam, Eugene Cheung, Matthew DiGioia, Mike Murphy, Gaurav Shah
  - **Undergrads:**
    - Alkas Baybas, Jason Boxerman, Jackie Cheung, Ezgi Ergec, Syed Hussain, Mitch Mason